

ADMINISTRATIVE INFORMATION

1. **Project Name:** Eaton Wireless Sensor Network for Advanced Energy Management Solutions
2. **Lead Organization:** Eaton Corporation
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5. **Date Project Initiated:** 01/01/04
6. **Expected Completion Date:** 12/31/2008

PROJECT RATIONALE AND STRATEGY**7. Project Objective:**

The Eaton WSN team will research, test, develop and deploy a Wireless Sensor Network (WSN) for the purpose of enabling significant energy savings and Advancing Energy Management Solutions (AEMS) in the Industries of the Future (IoF). The WSN will support open wireless protocols and be self-configuring, robust and secure in industrial environments.

According to DoE research, motors below 200 horsepower make up 98% of the motors in service and consume 85% of the energy used; therefore widespread deployment of energy management systems is critical in realizing the possible savings. Wireless sensor technology enables existing and new electrical distribution and power control systems to communicate and report information for diagnostics and prognostics purposes. Today, only a small percentage of this equipment is capable of communicating information due to cost of installation and the use of proprietary interfaces that are non-interoperable among different sensor manufacturers. The proposed Wireless Sensor Network (WSN) will provide a low-cost path to deliver voltage, current, power, load, and other key process information to facility/enterprise systems or applications. Eaton's WSN will enable these systems to save energy, provide diagnostics and prognostics, and improve uptime across the *entire* plant.

Understanding how the power is being used throughout the energy distribution system is first step in realizing these energy savings. Due to the high cost of installing monitoring equipment today, companies are restricted to deploying only limited, temporary instrumentation to make any assessments. Despite this, the information collected has proven to be helpful in optimizing power distribution systems. WSNs will enable a step change in energy management solutions by allowing widespread instrumentation and continuous, distributed monitoring of plant components.

8. Technical Barrier(s) Being Addressed: Challenging

The key research hurdles for the project include:

- Developing a WSN that operates with a variety of open wireless protocols
- Designing a WSN architecture that enables forward migration, while recognizing the need to support the legacy system supportability expectations of industrial customers
- Design of a self-configuration, multi-hop and redundant path capability using minimal microprocessor and memory resources to conserve power and meet cost targets
- Utilize improved radio technologies to address RF transmission issues expected in the industrial environments
- Assuring that WSN is properly integrated into the advanced energy management systems software
- Develop power-harvesting technologies for extension of the sensors beyond electrical systems to fluid and mechanical power systems applications.

9. Project Pathway

Eaton's 5-year WSN research and development project will proceed in three sequential phases. In **Phase I**, a baseline system will be developed. This baseline WSN will demonstrate feasibility of the basic networking concepts. Demonstrations will use wireless enabled sensors that consist of current, voltage, and other physical property sensors. Additionally, during this phase WSN requirements will be documented, alternative solutions will be assessed, design specifications will be developed and an initial test plan will be developed. In **Phase II**, the baseline WSN will be extended by addressing four critical issues. These issues will include ultra low power sensors and power harvesting, security, RF transmission in the industrial environment and power-aware routing. **Phase III** will provide for concept validation. During this phase an alpha system will be fielded at customer sites and commercialization plans to bring new energy management products to market will be developed. Applications will be identified, improvements will be made and a product introduction plan will be identified.

10. Critical Technical Metrics:

1. 80% reduction in the cost of installed sensors
2. Provide documentation to enable energy savings in the range of 11 to 18 percent resulting from deploying WSN enabled energy management solutions. This includes data for:
 - Improving motor rewinding practices and properly sizing motors to applications
 - Reducing system load requirements and reducing or controlling motor speed
 - Matching component size to load
 - Upgrading component efficiency and improving maintenance

The DoE's detailed analysis of the motor systems estimates that industrial motor energy use could be reduced by 11 to 18 percent if facilities managers undertook all cost-effective applications of mature proven efficiency technologies and practices.

PROJECT PLANS AND PROGRESS**11. Past Accomplishments:**

- Wireless technology assessment process defined. Initial population of database complete with standard wireless technologies.
- System requirements survey questionnaire complete.
- Review of installed wiring cost of sensors complete.

- Specification of lower layer baseline communications protocol stack complete. First simulation complete.
- Maintain leadership and active participation in relevant wireless communications consortia.
 - Leadership role in Wireless Industrial Network Alliance (WINA)
 - IEEE 802.15.4 Subcommittee.
 - Initiated efforts to create Wireless Industrial Communication Profile within the Zigbee Alliance.
- Opened two feasibility projects supporting integration of the wireless sensing technology developed under this Eaton/DOE program to two existing product lines in the domain of power management. Details of these programs will be presented in confidential reports of this project.

12. Future Plans:

- Generate and document WSN and AEMS requirements (July 2004)
- Investigate, assess and document alternative solutions. (July 2004)
- Design and prototype baseline wireless sensor network test bed. (Sept 2004)
- Develop and execute baseline test plan (Dec 2004)
- Extend baseline network. This will address ultra low power sensors/power harvesting, enhanced security features, power aware routing, packaging and environmental issues. (Jan 2006)
- Demonstration and testing of WSN in an industrial environment (Dec 2006)
- Identify applications and conduct alpha test site demonstration. Implement additional design improvements based on results. (July 2007)
- Implement Wireless network performance improvements (July 2008)
- Develop and implement product introduction plan covering the manufacturing, marketing, and introduction of the WSN into an energy management system optimization product. (Dec 2008)

13. Project Changes: None**14. Commercialization Potential, Plans, and Activities:** Describe the end-use application and market potential for the project, and the plans, progress, and partners for commercial application/adoption, where appropriate; identify what the product of the project will be and how this product will be introduced/disseminated to industry.

- Through WSN's, the installation cost of advanced energy management systems will be significantly reduced enabling broad deployment in the IoF. Furthermore, these systems will aid identification and implementation of energy savings through operational efficiency improvements.
- Eaton's Industrial Control distribution channels across the IoF and their Electrical Engineering Services and Systems organization, will help accelerate deployment
- Wireless nodes will be integrated into existing and future intelligent power distribution and monitoring products manufactured by Eaton
- Resolving robustness, security, reliability and ease of use issues of wireless technology will foster adoption of WSN in industrial applications.
- Eaton's active participation in standards bodies such as WINA, IEEE 802.15.4 and Zigbee will facilitate more rapid adoption of industrial wireless technology into the IoF.
- Other companies have committed to developing the needed radios and embedded software based on these standards to quickly deploy wireless networking solutions

- The Data from power distribution and control systems will be communicated via the wireless network back to Eaton's energy management diagnostic and control systems.

15. Patents, Publications, Presentations:**Related Patents Pending (filed) Not Funded by DoE Program:**

- “Hybrid Source Routing (HSR) Algorithm for Self-Configuring/Multihop Networks”
Jose A. Gutierrez and Luis R. Pereira
- “Wireless Network Clustering”
Charles Luebke and Jose A. Gutierrez.

Presentations, Papers and Books

- Jose A. Gutierrez, Edgar H. Callaway, Jr., and Raymond L. Barrett, Jr., “Low-Rate Wireless Personal Area Networks - Enabling Wireless Sensors with IEEE 802.15.4”, Standards Information Network, IEEE Press, 2003.
- Gutierrez, J., “Wireless Industrial Networking Alliance – Technical Committee Overview”, WINA Plenary Meeting at ISA Headquarter, North Carolina/February – 2004.
- Naeve, M. and Gutierrez, J., “Eaton Proposal for IEEE 802.15.4 Improvements”, IEEE 802 Jan-2004 Plenary. Orlando/January-2004.

In preparation:

- Gutierrez, J., “Wireless Sensor Network Applications for the Industrial Environment”, Wireless Sensing Solutions Conference – Chicago/Sept. – 2004.
- Gutierrez, J., “Enabling Industrial Wireless Sensor Networks with IEEE 802.15.4/LR-WPAN technology: Opportunities and Challenges”, ISA - Wireless Sensor Symposium - Michigan/June 2004.
- Gutierrez, J., “Paving the Road for Wireless Industrial Sensor Networking”, Sensors Expo - Michigan/June 2004.